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Impacts of Temperatures on Biogas Production in Dairy Manure Anaerobic Digestion

Pramod K. Pandey and Michelle L. Soupir

Abstract—Batch anaerobic digestion of dairy manure was performed at low (25 °C), mesophilic (37 °C), and thermophilic (52.5 °C) temperatures to determine the influences of temperatures on biogas production. The experiment was run for 76, 40 and 29 days at 25, 37, and 52.5 °C, respectively. The biogas production was measured daily at each temperature. To estimate the solid reductions, we measured total solids (TS) and volatile solids (VS) over time. The biogas production at 52.5 °C and 37 °C were 49 and 17 times higher than that at 25 °C. Over incubation periods, the TS reduction at 25, 37, and 52.5 °C were 5.6, 57, 34%, respectively. The VS reductions were 127, 58.4, 42.5%, respectively. At 25 and 37 °C, pH was reduced, while at 52.5 °C pH was increased. The Oxidation Reduction Potential (ORP) values at 37 and 52.5 °C were negative over the incubation period. But at 25 °C, however, the ORP values were positive after Day 19. Findings from this study are useful for enhancing anaerobic digesters' performance.

Index Terms—Anaerobic digestion, biogas production, TS, VS, ORP.

I. INTRODUCTION

The anaerobic digestion of dairy manure has significant importance as it produces biogas – a source of energy. The application of anaerobic digesters for biogas production and manure treatment is well established and has been implemented all over the world. The use of biogas produced in anaerobic digestions of dairy manure as a renewable energy source is popular in many less-developed countries, where economic conditions limit the availability of fossil fuel. The biogas produced from anaerobic digestion of dairy waste is used as fuel for heating and cooking. Besides generating biogas for energy use, the anaerobic process also reduces solid waste [1].

A large amount of research has been conducted on anaerobic digestion process to enhance biogas production [2, 3, 4]. However, relatively, less emphasize has been made on evaluating the temperatures influencing biogas production and solids reductions in dairy manure anaerobic digestion. The objective of this study is to determine the impact of temperatures on biogas production as well as solids reduction.

II. METHODS

Fresh manure was collected from Iowa State University's dairy facility 24 hours prior to the start of the experiment to

prepare the feedstock for the anaerobic reactors. To prepare the feedstock, 0.498 kg of fresh manure was mixed thoroughly in 1,500 ml of distilled water. Fibers and large solid particles in the manure were removed. One hundred fifty ml of feedstock was transferred into each reactor, and then the reactors were sealed with a rubber septum. Experiments were conducted for low temperature, mesophilic temperature, and thermophilic temperature at 25, 37, and 52.5 °C, respectively. Each experiment included six anaerobic batch reactors, 250 ml serum bottles for incubating the feedstock. To ensure anaerobic conditions within the reactors, the air above the feedstock was removed. The water bath shaker was used to control the reactors' temperatures; water bath shaking speed was maintained at 150 rpm. A gas tight glass syringe was used to collect the biogas and liquid from the reactors. Methane content of the biogas, total solids (TS) and volatile solids (VS) were analyzed according to Standard Methods [5].

III. RESULT AND DISCUSSION

The influence of temperatures in biogas production is shown in Fig. 1. At 52.5 °C, the biogas production in reactors began between 12 and 14 hours; however, at 37 °C and 25 °C, biogas production was first detected on day 25 and 61, respectively. Biogas production at 52.5 °C ceased on day 15, while at 37 °C, biogas production continued until Day 40. At 25 °C, only a slight amount of biogas was produced on day 61 and 62. The cumulative biogas production at 52.5 °C was 541 ml over 28 days of incubation period. At 37 and 25 °C, the cumulative biogas production was 193 and 11 ml over 41 and 62 days of incubation periods, respectively. Compared to 25 °C, biogas production at 52.5 °C and 37 °C was 49 and 17 times greater. Methane content in biogas at 52.5 °C was approximately 70%, while at 37 °C it was about 55%; methane content at 25 °C was not measured as a very small amount of biogas was produced. Similar to these results, Zhang [6] also found high amount of gas production (within 10 days) during thermophilic digestions of food waste.

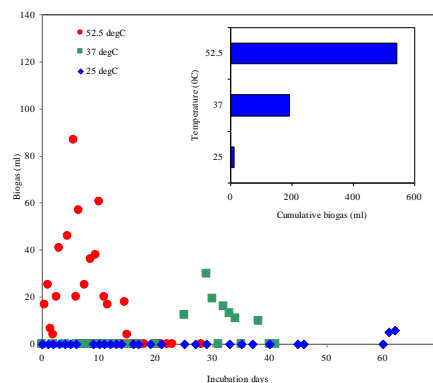


Fig. 1. Biogas production at different temperatures.

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Total solid (TS) and volatile solid (VS) reductions are shown in Fig. 2A and 2B, respectively. The TS and VS at 52.5°C varied between 1.13-1.9% and 0.73-1.5%, respectively. The TS variation at 37°C and 25°C were from 1.4 to 2.04%, and from 1.04 to 1.6%, respectively.

The VS changes at 37°C and 25°C were from 1.3 to 1.7%, and from 0.48 to 1.24%, respectively. The TS at the end of day 29, 40, and 76, at 52.5, 37, and 25°C were found 1.15, 0.62, 1.32%. The VS at the end were 0.7, 0.47, 0.49%, respectively (Table 1). The TS at 52.5, 37, and 25°C were reduced by 34.02, 56.96, 5.6%. The VS was reduced by 42.9 58.4, and 127.78%, respectively (Table 1).

The variation in pH and ORP is shown in Fig. 2C and 2D, respectively. At 37 and 25°C, pH was reduced over time and both temperatures show similar patterns, however, at 52.5°C, pH increased. At 52.5°C pH increased about 8.13%, while at 37 and 25°C, pH decreased, 8.38 and 6.9%, respectively.

The ORP values in both 52.5 and 37°C temperatures were negative, however, at 25°C the ORP was positive after day 19. The ORP ranges at 52.5 and 37°C were from -365 to -217 and from -360 to -150 mV, respectively, and at 25°C this range was from -325 to 181. The ORP values indicate oxidation/reduction potential. Kuo and Lai [7] have also reported negative ORP values in anaerobic digestions of food waste, and found that increased ORP reduces digestion performance. The positive ORP at 25°C indicates low redox potential, which might have caused the low biogas production in the reactors. Methanogens, which produce biogas are more active at low ORP values.

The average pH at 52.5, 37, and 25°C over the incubation periods were 7.8, 6.9, and 7.0, respectively. The average ORP at 52.5, 37, and 25 over incubation period were -298, -265, 26.36 mV, respectively. Riau [8] reported alkalinity

imbalance at thermophilic temperatures; a longer incubation period under thermophilic conditions increased pH values. Our results of pH are similar to Rio's study, who reported that anaerobic reactors at mesophilic temperature have better buffering capacity and maintained pH values close to 7.0. The pH ranges are similar to the results reported by Zhang [6] and Sung [8].

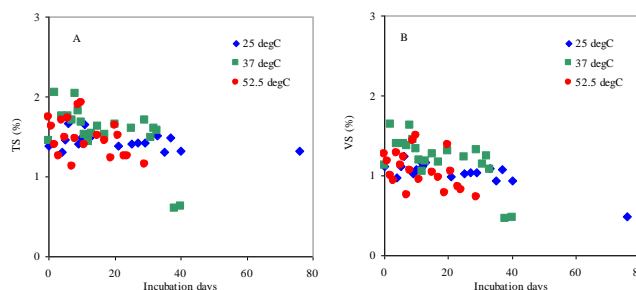


Fig. 2. Total solid (A) and volatile solids (B) reduction

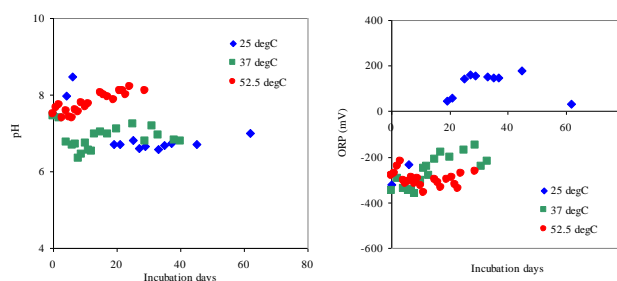


Fig. 3. Changes in pH and ORP

TABLE I: TEMPERATURE INFLUENCE IN PARAMETERS.

Parameters	25 °C			37 °C			52.5 °C		
	Initial	Final	Reduction (%)	Initial	Final	Reduction (%)	Initial	final	Reduction (%)
pH	7.5	7.0	7.3	7.4	6.8	8.4	7.5	8.1	8.1
TS (%)	1.4	1.3	5.6	1.5	0.6	57.0	1.8	1.2	34.0
VS (%)	1.1	0.5	127.8	1.1	0.5	58.4	1.3	0.7	42.5
ORP (mV)	-320	32.5	+	-346	-346	-	-280	-265	-

*in reduction column, negative sign indicate decrease and positive signs indicated increase

IV. CONCLUSIONS

This research evaluated the impacts of temperature on biogas production in anaerobic digestion of dairy manure. Results show that biogas production under thermophilic temperature conditions could be several times higher than the biogas production at mesophilic and low temperatures. During thermophilic digestion, the onset of biogas was much quicker compared to the other temperatures. The methane content of the biogas and solids reduction were also greater at the thermophilic temperature. The ORP values were positive at 25°C, while at 37 and 52.5°C, those were negative.

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